Reinterpreting Precision Experiments as Michelson–Morley Tests for an Information-Theoretic Ether

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The Michelson–Morley experiment did not merely refute a particular mechanical model of the luminiferous aether; it inaugurated a new standard for what it means to test a hidden medium. Aether hypotheses only became scientifically meaningful once they implied concrete, quantitative deviations from established dynamics. In this paper, we argue that today's speculative "information-theoretic ether" stands at a similar crossroads. If a universal informational field τ underlies physical processes q, then at least some τ-models should already be constrained by experiments that were never framed in those terms. Rather than designing a brand-new device, we reinterpret existing precision experiments as de facto Michelson–Morley tests for τ. We develop minimal, operational parameterizations of an information field and map them onto familiar observables: correlated position noise in interferometers, orientation-dependent resonance shifts in optical cavities, and statistical deviations in Bell tests and quantum random number generators. We then read the null results of the Fermilab Holometer, gravitational-wave interferometers, modern Lorentz-invariance tests, and loophole-free Bell experiments as upper bounds on τ–q coupling. This reinterpretation narrows the viable space for informational-ether models and clarifies what kinds of τ remain empirically unconstrained. The result is a concrete research program: information-ether theories must either match these bounds or propose new, testable channels that current experiments cannot yet see.

Keywords: Michelson–Morley, information-theoretic ether, τ-field, logostics, vacuum fluctuations, Holometer, LIGO, Lorentz invariance, Bell tests, QRNG, Born rule, quantum vacuum, precision interferometry, preferred frame, holographic noise.

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1. Introduction: From Optical Aether to Informational Ether

The story of the aether is usually told as a cautionary tale: a hypothetical medium introduced to save a theory, defended by increasingly elaborate adjustments, and finally swept away by a single great experiment and a new symmetry principle. That narrative is tidy but incomplete. What Michelson–Morley actually did was sharper and more methodological: it showed how to turn a vague metaphysical medium into a concrete physical hypothesis that can be ruled out by a carefully designed null result.

Today, when people speak about an "information-theoretic ether" or a universal informational field underlying quantum fields and spacetime, we are in a similar position. The language is evocative, the metaphors are rich, but the operational content is often left unspecified. Without clear couplings to measurable systems, an informational ether risks becoming a rebranding of existing structures rather than a testable extension beyond them.

This paper proposes to treat "information ether" with the same discipline that Michelson and Morley, and later Einstein and Lorentz, applied to the optical aether. Instead of designing a new iconic experiment from scratch, we take seriously the idea that many such experiments have already been done. Precision interferometry, cavity resonance tests, loophole-free Bell experiments, and long-running quantum random number generators have all been performed and analyzed under other names. We ask: in what sense have these already been Michelson–Morley experiments for an informational field, and what do their null results tell us about which kinds of information ether remain viable?

To make this concrete, we introduce a minimal notation in which tau(t) denotes a putative informational field and q(t) denotes the physical systems and configurations that our apparatus actually probes. We then show how different classes of experiments can be reinterpreted as constraints on possible tau-to-q couplings. The move is modest but important: we are not inventing a new metaphysics, but translating existing data into a language capable of supporting or excluding specific informational models.

1.1 Historical role of Michelson–Morley as a template for null tests

Michelson and Morley did not go looking for "nothing". They were looking for a very specific something: an "aether wind" implied by the simplest mechanical models of a stationary luminiferous aether. If light propagated as a wave in a fixed medium while the Earth moved through that medium, then the speed of light measured along the Earth's motion should differ slightly from the speed measured across it. The prediction was quantitative: the difference should scale like v^2 / c^2, with v the Earth's orbital speed and c the speed of light.

The genius of their interferometer was not merely sensitivity; it was the way sensitivity was deployed. By splitting a beam into two perpendicular arms and recombining them, the device translated tiny differences in light travel time into visible fringe shifts. By rotating the apparatus, they modulated any putative wind signal as the orientation of the arms changed with respect to the Earth's velocity. The experiment was intrinsically differential and intrinsically modulated: it was designed to see a changing signal against a stable background.

The result was famously null. The expected periodic fringe shift did not appear, at least not at the predicted scale. Initially, this was treated as a puzzle within the aether framework itself, giving rise to ad hoc fixes such as length contraction and time dilation attached to moving objects. Only later was the null properly understood as evidence that the underlying symmetry principle had been misidentified. The lesson is methodological: a powerful null experiment does not simply "disprove" a medium. It discredits an entire class of models that predict certain anisotropies, and it invites a symmetry-based reformulation in which the old medium either becomes superfluous or changes character entirely.

Modern physics repeats this pattern. Precision tests of charge conservation, Lorentz invariance, and the equivalence principle are often designed as next-generation Michelson–Morley experiments: high-sensitivity, differential, modulated measurements targeting specific deviations from accepted symmetries. The point is not that such tests prove a symmetry absolutely, but that they squeeze the space of viable alternatives. This is precisely the role we propose for experiments reinterpreted as tests of an information-theoretic ether.

1.2 The shift from mechanical media to fields and symmetries

The downfall of the luminiferous aether was not only an experimental event; it was a conceptual realignment. Classical physics had inherited the intuition that waves require media: sound in air, ripples in water, shear waves in solids. Light, understood as an electromagnetic wave, was expected to fit the same pattern. The aether was introduced as a mechanical medium with definite properties, filling space and supporting the propagation of transverse electromagnetic waves.

The failure to detect an aether wind, together with the success of Maxwell's equations and the new relativity principle, gradually replaced this picture with a more abstract one. Instead of asking "what stuff is waving?", physicists learned to speak directly of fields: entities defined at each spacetime point, obeying differential equations and transformation laws. The question "what is the electromagnetic field made of?" gave way to "how does it transform under Lorentz transformations, and how does it couple to charges?". The ontological focus shifted from a substrate to the pattern of symmetries and interactions.

This shift did not make medium thinking impossible; it made it optional. One can still speak of the electromagnetic field as a kind of medium if one wishes, but the choice carries no extra predictive burden. There is no measurable difference between “light waves in an aether” and “field excitations in vacuum” so long as the equations and symmetry principles are the same. The aether becomes a story you tell yourself about fields, not an independent entity that can be probed.

Quantum field theory radicalizes this further. The vacuum is no longer a simple absence but a structured ground state with fluctuations, condensates, and nontrivial topology. Yet even here, the decisive ingredients are symmetries, correlation functions, and observable spectra. When the vacuum is said to “have structure,” this is shorthand for specific patterns in correlation functions and responses to probes. The ontology is thin: we infer what the vacuum is from what it does.

The idea of an information-theoretic ether arrives in this context. It often suggests a new substrate, more fundamental than fields, in which information is the primitive and energy, matter, and spacetime are derived. But unless this informational substrate implies new patterns in the correlations we already measure, it risks repeating the pre-relativity aether mistake: multiplying entities without altering predictions. The path forward is to learn from the historical shift toward fields and symmetries, and to apply the same discipline to informational talk.

1.3 Motivations for an information-theoretic ether today

Despite the success of field theories and symmetry-based descriptions, the appeal of an informational substrate has grown rather than diminished. Several strands contribute to this.

First, there is the statistical and computational reading of quantum theory. From quantum Shannon theory to quantum computing, much of the formalism can be rephrased as statements about the transformation and limitation of information. Entanglement entropy, channel capacities, and quantum error-correcting codes encourage the intuition that what is conserved or transformed most primitively is information, with energy and matter as derived bookkeeping devices.

Second, there are holographic and black-hole arguments suggesting that the maximum number of distinguishable states inside a region scales with its boundary area, not its volume. This “area law” for entropy invites a picture in which the detailed state of a bulk region is encoded in a lower-dimensional boundary structure, as if physical space were an emergent interface over some deeper informational manifold.

Third, there is the pragmatic success of treating complex systems, from condensed-matter phases to biological networks, in informational terms: as patterns of correlations and causal influence rather than mere configurations of particles. This makes it natural to ask whether spacetime and fields themselves are emergent from some large-scale organization of informational degrees of freedom that do not manifest directly as particles or forces.

Finally, there is the desire for unification. Information, in its mathematical form, is remarkably domain-agnostic. The same concepts of entropy, mutual information, and algorithmic complexity can be applied to gravitational waves, DNA sequences, or financial time series. An information-theoretic ether would be a conceptual unifier: a single substrate from which disparate physical and computational phenomena arise as modes or excitations.

These motivations are compelling, but they do not by themselves yield a physical theory. They suggest the existence of a deeper informational level, but they are silent about how such a level couples to the systems we actually measure. This is where the analogy with the old aether becomes useful. If an informational ether is to be more than a redescription, it must leave some trace in the correlations, noise spectra, or anisotropies that our existing apparatus already probes with exquisite sensitivity. To see whether it does, we need a minimal parameterization of that ether and a way to translate it into experimental signatures.

1.4 tau as informational field, q as physical systems: basic notation

To keep the discussion focused and to make contact with logostic language, we adopt a simple separation of roles. We write tau(t) for a putative informational field or manifold and q(t) for the physical systems that our instruments interrogate. The time variable t here stands generically for whatever temporal parameter is relevant to the experiment at hand; we will not insist on a specific spacetime formalism in the introduction.

The field tau(t) is not assumed to be a classical field in the usual sense. Instead, it plays the role of “whatever carries the deeper informational structure” that one might wish to posit beneath quantum fields and spacetime. It may be continuous or discrete, local or nonlocal, classical or quantum; we deliberately keep it agnostic. What matters is that some models of tau allow it to influence or constrain the evolution and statistics of q.

The variables q(t) represent the conventional degrees of freedom we already know how to model: mirror positions and phases in an interferometer, electric fields in a cavity, qubit states in a Bell experiment, bits in a quantum random number generator. In standard physics, the dynamics and statistics of q(t) are fully determined by known Hamiltonians, noise sources, and boundary conditions. In an informational ether picture, we allow for the possibility that q(t) also carries a subtle dependence on tau(t) beyond what is captured by those standard ingredients.

To speak meaningfully about an experiment as a test of tau, we need to specify how tau enters. In the simplest case, tau could manifest as an additional noise term, adding a stochastic contribution delta q_tau(t) with a particular spectrum and correlation structure. In a more structured case, tau could define a preferred frame or direction, so that certain observables depend on the orientation of the apparatus with respect to a vector or tensor derived from tau. In a still more radical scenario, tau could slightly modify the rules by which q probabilities are assigned, leading to tiny deviations from standard quantum statistics.

In all of these cases, the experimental move is the same. We write the observable O[q] predicted by standard theory, then add a parametrized contribution delta O[tau] representing the effect of the information ether. A Michelson–Morley-type experiment is one in which O[q] is predicted to be constant or symmetric in some way, while delta O[tau] would introduce a small but structured deviation: a modulation with rotation, a correlated noise floor between nominally independent devices, or a systematic bias in probability distributions. The absence of such deviations within experimental sensitivity then becomes a bound on the parameters encoding the tau-to-q coupling.

In the rest of the paper, we will use this tau and q notation as a bookkeeping device rather than a fully developed theory. It allows us to speak of “tau-induced transverse jitter” in an interferometer, “tau-aligned anisotropy” in a cavity resonance, or “tau-correlated deviations” in Bell statistics without committing to a detailed microscopic model. The goal is not to settle what tau is, but to clarify what kinds of tau could have shown up in experiments that, so far, have reported only nulls.

2. What It Means to Test an Information Field

If one speaks about an informational field underneath familiar physics, the temptation is to stay at the level of metaphors. The field becomes a poetic background: a sea of bits, a universal code, a substrate of meaning. None of that yet counts as physics. To reach the level where experiments can agree or disagree with the proposal, one has to specify how this field enters the dynamics and statistics of the systems we actually measure.

Testing an information field therefore begins with a distinction. On one side is ontology: the story we tell about what is really there. On the other side is operational content: the patterns that must appear in data if that story is more than a relabeling of existing structures. The history of the optical aether shows that the mere idea of a medium is not enough. It becomes physics only when coupled to a concrete prediction that differs from established theories.

In this section, we make that distinction explicit and outline the minimal ingredients needed to promote an informational ether from metaphor to testable hypothesis. We sketch simple tau-

models that add noise, define preferred frames, or slightly deform quantum probabilities. We then show how these deformations map onto the observables that interferometers, cavities, and quantum experiments already report. Finally, we extract a generalized Michelson–Morley pattern: modulation, differential measurement, and an expectation of null results in the absence of a tau effect.

2.1 Ontology versus operational content: when ether talk becomes physics

There are two ways to speak about an information field. The first is purely interpretive. One can say that the quantum state, the gravitational field, or the entire universe is "really" information, or that the vacuum is a code running on some deeper substrate. Provided the equations and predictions remain unchanged, this is an ontological gloss. It may have philosophical or theological significance, but experiment cannot adjudicate between such descriptions.

The second way is operational. Here, the claim is not merely that reality can be described in informational terms, but that there exists a specific field tau that affects the behavior of physical systems q in ways not already captured by known theories. In other words, tau is not just a way of speaking about the quantum state or the metric; it is an additional structure whose presence or absence makes a difference in measured outcomes.

The transition from the first style of talk to the second is subtle but decisive. It occurs when one can say: if tau has property X or coupling Y, then observable O, which is predicted to be constant or symmetric in standard theory, will instead exhibit a pattern P. The moment one can identify a concrete, measurable pattern that would not exist if standard theory were complete, ether talk becomes physics.

This is the point at which historical analogies become useful. The optical aether passed from interpretive convenience to testable hypothesis when specific models predicted a relative shift in light speed between two perpendicular arms of an interferometer. In the same way, an informational ether becomes testable when some tau-structure demands, say, a small anisotropy in phase noise or a tiny deviation in quantum statistics that is absent from conventional models. Without such commitments, one can only argue about pictures, not about the world.

2.2 Minimal tau-models: noise injection, preferred frames, and Born-rule deformations

To move beyond metaphors without pretending to have a full theory, it is useful to adopt minimal, phenomenological tau-models. These do not claim to capture the true microphysics of

an informational field. Instead, they specify the simplest possible ways tau could leave a trace in experiments. Three classes are particularly natural.

The first class treats tau as a source of additional noise. Here, tau contributes a stochastic term delta q_tau(t) to the evolution of physical variables q(t). The key feature is not just that there is extra noise, but that its statistics have a characteristic structure: a specific spectrum, cross-correlation between nominally independent devices, or dependence on orientation or time of day. Correlated position noise between two nearby interferometers, or a shared low frequency jitter that cannot be traced to known environmental sources, would be examples.

The second class treats tau as defining a preferred informational frame or direction. In purely field theoretic language, this would correspond to a violation of full Lorentz invariance in favor of a frame singled out by tau. Operationally, it means that some observable depends, however weakly, on the orientation of the apparatus relative to a fixed spatial direction or on the velocity of the lab relative to a cosmic rest frame. Modern tests of Lorentz invariance already bound such effects in terms of small coefficients. The same formalism can be used to constrain tau-induced anisotropies.

The third class is more radical and targets probabilities themselves. Instead of modifying dynamics or adding noise, tau slightly changes the rule that maps amplitudes to outcome frequencies. Standard quantum mechanics uses the Born rule. A tau-deformed model might predict that certain outcomes occur with probabilities that differ from the Born values by a small tau-dependent factor, perhaps modulated by orientation, time, or entanglement structure. In such models, long runs of quantum random number sequences or repeated Bell tests become direct probes of tau, because even tiny biases or excess correlations can be detected given enough data.

Each of these minimal models is deliberately coarse. They do not describe how tau is generated or evolves; they simply encode how tau would make itself known. By working with these simple classes, one can reuse experimental work already done for other purposes and re-express their null results as constraints on noise spectra, anisotropy coefficients, or probability deviations attributable to an informational field.

2.3 Mapping tau-perturbations onto observables: phase, position, probability

Experiments never measure tau directly. They measure phase shifts, positions, frequencies, switching events, and counts. To reinterpret existing data as tests of an information field, one must map tau-perturbations onto those observables. At a schematic level, three channels are most important.

The first is phase. Optical and microwave interferometers, from tabletop devices to gravitational-wave observatories, are exquisitely sensitive to changes in phase along different paths. A tau-induced perturbation to the effective optical path length, or to the phase accumulation per unit time, appears as a small, possibly time-dependent shift in interference fringes or resonance conditions. If the perturbation is correlated between distinct interferometers, or depends on orientation relative to a fixed direction, it stands out against uncorrelated instrumental noise.

The second is position. Mirror locations, test mass separations, and cavity lengths can be tracked directly or indirectly through their influence on resonance frequencies. A tau model in which positional degrees of freedom are subject to a fundamental jitter or graininess would imply a specific spectral density of apparent position fluctuations. These may be most easily accessed indirectly, through their imprint on phase, but in some designs direct displacement sensing is also available. Again, the hallmark of tau would not be noise alone, but noise with a distinctive correlation pattern or scaling.

The third is probability. In quantum experiments, the raw data are sequences of outcomes: detector clicks, qubit readouts, time tags. Standard theory predicts not just mean frequencies but full distributions and correlation functions. A tau-induced modification of the probability rule would manifest as a small, structured deviation from these predictions. For example, in a Bell test, the frequency of joint outcomes in given measurement settings might drift systematically in a way not attributable to known drifts. In a quantum random number generator, long sequences might exhibit biases or algorithmic compressibility that track external orientation or cosmic time.

In each case, the mapping from tau to observables can be captured by a small number of parameters: an added spectral density for phase or position noise, a set of anisotropy coefficients, or a bias parameter in probability distributions. This reduction is important. It allows one to take published noise budgets, spectral plots, and statistical analyses and read them as bounds on these tau parameters, rather than requiring access to raw data or a complete reanalysis.

2.4 The Michelson–Morley pattern generalized: modulation, differential measurement, null expectation

The original Michelson–Morley experiment embodies a pattern that can be generalized for testing tau. Three elements define this pattern: modulation, differential measurement, and a null expectation under the standard theory.

Modulation means that the predicted tau effect should vary in a controlled way as some parameter is changed: orientation, time, frequency, or configuration. Michelson and Morley rotated their interferometer so that any aether wind would alternately align with one arm and then the other, producing a periodic fringe shift. In a tau context, modulation might come from Earth's rotation and orbit, from deliberate rotation of an apparatus, or from switching between configurations designed to amplify or suppress tau coupling. A static offset is easy to confuse with calibration error; a modulated signal is much harder to ignore.

Differential measurement means that the experiment compares two paths, states, or devices, rather than relying on an absolute reading. The interferometer measures a difference in travel time between arms. Modern cavity experiments compare resonance frequencies along different directions. Bell tests compare joint outcome statistics under different measurement settings. Differential designs automatically cancel many common-mode errors and drifts, leaving only differences that have a chance of revealing a tau imprint.

The null expectation is the final ingredient. Under standard theory, the differential observable is predicted to be constant or symmetric in the face of the modulation. Any deviation is therefore meaningful. Michelson–Morley expected zero average fringe shift over a rotation in the absence of an aether wind. Likewise, if conventional quantum theory and relativity are complete, phase noise in identical interferometers should be uncorrelated beyond known technical couplings, and outcome statistics in separated Bell tests should obey the standard distributions with no extra structure.

To generalize Michelson–Morley to an information field, one designs or reinterprets experiments so that tau would introduce a small, structured modulation into a differential observable that is otherwise expected to remain null. One then uses the absence of such modulation, within the sensitivity of the apparatus, as a bound on tau-induced effects. This is the basic pattern we will apply in the subsequent sections, using existing interferometers, cavity tests, and quantum experiments as already executed, if unheralded, Michelson–Morley experiments for an informational ether.

3. Criteria for a Michelson–Morley-Type Experiment in tau-Language

To reinterpret or design experiments as Michelson–Morley tests for an informational field, we need a clear set of criteria expressed directly in tau-language. The original interferometer did not test "the aether" in general; it tested a concrete prediction about a specific observable: an orientation-dependent difference in light travel time between two arms. In the same way, a tau-experiment must target a well-defined quantity whose behavior is fixed by standard theory and only altered if tau couples to physical systems in a particular way.

This section spells out the main criteria. First, the observable must be tau-sensitive but theory-clean: its expected value and fluctuations should be sharply constrained by established dynamics and noise models. Second, the experiment should exploit rotation, orbital motion, or other periodic modulations that would turn a tau field into a time-dependent “wind” or bias. Third, it should be formulated in differential terms so that common-mode errors cancel and only tau-induced differences remain. Finally, we must know how to convert existing experimental error budgets, reported in ordinary engineering and physics language, into explicit bounds on tau-parameters.

3.1 Defining a tau-sensitive but theory-clean observable

The first criterion is conceptual clarity. An experiment can only test tau if it measures something whose expected behavior under tau equals zero is well understood. The observable must be tau-sensitive in the sense that reasonable tau-models predict a deviation, but it must also be theory-clean in the sense that standard physics makes a precise prediction in its absence.

This rules out quantities that are already dominated by uncontrolled environmental noise or by poorly understood systematics. For example, the absolute phase of a single laser beam drifting over hours is a poor candidate; it is sensitive to temperature, mechanical drift, and power fluctuations, and there is no simple baseline calculation for how it ought to behave. By contrast, the phase difference between two arms of a stabilized interferometer, or the frequency difference between two orthogonal cavity modes, can be modeled to high accuracy within known theories and noise mechanisms.

A tau-sensitive observable is one that would respond in a distinctive way if an informational field injected extra noise, defined a preferred frame, or deformed probabilities. This might be a cross correlation between two nominally independent interferometers, an anisotropy in resonance frequency as an apparatus is rotated, or a small bias in outcome frequencies across long runs of a quantum experiment. What all of these share is that, under standard theory, their expectation value or modulation amplitude is essentially zero once known systematics are accounted for. The closer we can bring this baseline to zero, and the more tightly we can bound its fluctuations, the more discriminating the experiment becomes as a tau-test.

3.2 Rotation, orbital motion, and sidereal modulation as signatures of a tau-wind

A defining feature of the original Michelson–Morley setup was its use of the Earth’s motion. If there had been a luminiferous aether at rest in a cosmic frame, then the laboratory would have been moving through it, and there would have been an effective “aether wind” in the lab frame.

Rotating the interferometer in that wind was expected to produce a characteristic modulation in the interference pattern over a half turn.

Generalized to tau-language, the same logic suggests that we look for tau-winds: effective directions in which the coupling between tau and q differs from that in orthogonal directions. Such a wind could be associated with a cosmic preferred frame, with a gradient in the informational field, or with some anisotropic structure in the underlying informational manifold. Whatever its origin, the operational question is whether the laboratory's periodic motion relative to this structure imprints a periodic modulation on the tau-sensitive observable.

Rotation of the apparatus around a vertical axis is the simplest and most controlled modulation. As an interferometer, cavity, or quantum setup turns, any tau-induced anisotropy in phase, position, or probability should generate a signal that oscillates with the rotation angle. On longer time scales, the Earth's own rotation and orbit provide further modulations. A tau-wind fixed in a cosmic frame would lead to daily and yearly variations in orientation, even for a fixed apparatus. Conversely, the absence of any sidereal or seasonal modulation at the expected frequencies becomes a powerful constraint on such winds.

The criterion, then, is that an experiment designed or reinterpreted as a tau-test should either incorporate controlled rotation or at least run long enough and with sufficient stability that sidereal and orbital modulations could, in principle, be resolved. Without such modulation, tau-effects that behave like a wind are too easily confused with static miscalibrations. With modulation, they leave a distinct signature in the time series that can be searched for and bounded.

3.3 Differential versus absolute measurements: why nulls are powerful

The second major criterion is that the experiment be differential rather than absolute. Michelson and Morley did not attempt to measure the absolute speed of light with unprecedented accuracy. They measured the difference in travel times between two perpendicular paths, and then watched how that difference changed as the apparatus rotated. This differential design made their experiment extraordinarily sensitive to anisotropies while remaining robust against common-mode effects.

In tau-language, the same principle applies. A tau-field that couples identically to all parts of an apparatus will often be indistinguishable from a small global shift in phase or frequency that can be absorbed into calibration. What makes tau visible is not its absolute influence, but its tendency to act differently along different directions, locations, or configurations. Differential observables are precisely those that are blind to uniform shifts but sensitive to relative changes.

This is why null experiments are so powerful. If standard theory predicts that a differential quantity should be identically zero in the absence of tau, then any nonzero measurement, especially with a structured dependence on orientation or time, is immediately interpretable. More importantly, a measured value consistent with zero within known error bars can be turned into a quantitative upper bound on tau-parameters. The null is not empty; it is a statement of exclusion.

Absolute measurements, by contrast, often suffer from large systematic uncertainties and a lack of clean zero points. They are valuable for many purposes, but they make poor Michelson–Morley tests. An information-field hypothesis survives too easily if one is allowed to tune an overall scale or offset. Differential, null-based designs deny that freedom and force tau into the open, or else tighten the constraints on its possible couplings.

3.4 How to translate existing experimental error budgets into tau-parameter bounds

Once a tau-sensitive, theory-clean, differentially defined observable has been identified, the final step is translation. Most high-precision experiments already come with detailed error budgets and sensitivity curves, but they are expressed in conventional terms: strain noise as a function of frequency, frequency stability in parts per trillion, statistical uncertainties in measured probabilities. To turn these into bounds on tau, a mapping is required.

The mapping begins with a simple parameterization of how tau would affect the observable. For a noise-type tau model, one might posit an added spectral density S_tau(f) contributing to phase or displacement fluctuations. For a preferred-frame model, tau could be encoded in a set of small coefficients multiplying direction-dependent terms in the resonance frequency or speed of light. For a probability-deformation model, tau might be captured by a bias parameter epsilon that shifts outcome frequencies away from their standard values in a way that depends on orientation or time.

Given such a parameterization, one can write the total predicted observable as the sum of the standard contribution and the tau contribution. The published error budget, which typically includes all known noise sources and systematics, can then be viewed as a constraint on any additional, unmodeled contribution. If the measured noise floor or residual modulation is consistent with the standard prediction to within some margin, then any tau-induced term must lie inside that margin.

In practice, this translation often reduces to reading off or slightly reprocessing existing plots and tables. A reported upper limit on orientation-dependent frequency shifts can be reinterpreted as a bound on the magnitude of tau-induced anisotropy coefficients. An absence of correlated noise between two interferometers above a certain level can be expressed as an

upper limit on S_tau(f) in the relevant frequency band. Statistical confidence intervals on outcome frequencies in Bell tests or quantum random sequences bound the size of any tau-induced bias epsilon.

The essential criterion is that the mapping preserve meaning. One must be explicit about which tau-model class is being constrained and which parameter is being bounded. Different experiments will bound different combinations of tau-parameters. The virtue of the Michelson–Morley pattern is that it often singles out particular linear combinations that are especially clean. By systematically applying this procedure to existing error budgets, one can transform a pile of null results into a structured set of quantitative constraints on an informational ether, without having to build a new generation of specialized apparatus from scratch.

4. The Fermilab Holometer as a Transverse tau-Jitter Experiment

Among all modern precision experiments, the Fermilab Holometer comes closest in spirit to a direct probe of informational structure in spacetime. It was explicitly designed to test the hypothesis that space at macroscopic scales might exhibit a fundamental positional indeterminacy tied to holographic information bounds. In its original formulation, this was framed as a specific model of holographic noise: a Planck-scale limit on how finely positions can be defined, leading to measurable transverse jitter of mirrors in an interferometer.

Seen through tau-language, the Holometer can be reinterpreted as a dedicated search for tau-correlated noise in the transverse degrees of freedom of space. Two co-located interferometers were used not just to measure ordinary noise but to isolate any component that is common between them yet not attributable to known environmental couplings. That common-mode, nonclassical noise is exactly where an informational field would most naturally leave a trace if it altered the fine-grained structure of position.

This section revisits the Holometer with that perspective. We begin by recalling its original aims in terms of holographic noise and finite positional information. We then describe how the two-interferometer geometry turns it into a tau-correlated noise detector in our notation. Next, we sketch how the excluded noise spectrum can be reparameterized as an upper bound on an information density I_tau. Finally, we discuss what classes of tau-models are already ruled out by its null result, and which remain untouched.

4.1 Original aims: holographic noise and finite positional information

The Holometer was motivated by a particular reading of the holographic principle: that the information content of a spatial region is bounded by the area of its boundary, measured in

Planck units. If that is taken seriously as a statement about the fundamental degrees of freedom of spacetime itself, then ordinary coordinates may be over-resolving reality. Positions might not be continuously definable at arbitrary precision. Instead, there could be a finite, discrete set of distinguishable transverse positions over a given length scale.

In one concrete model, this limitation leads to a kind of holographic noise. Instead of spacetime points forming a rigid, continuous grid, the transverse positions of worldlines and mirrors would wander by a tiny but correlated amount set by an effective Planckian uncertainty. This jitter would not be like thermal or seismic noise, which arise from local forces on mirrors. It would be intrinsic to the geometry itself, showing up even in an otherwise perfectly quiet apparatus.

The Holometer's aim was to detect or exclude this jitter by measuring the relative positions of mirrors in long-baseline Michelson interferometers at high bandwidth. The prediction was that holographic noise would produce a specific, nearly white spectral density of transverse displacement noise, with correlations at the scale of the interferometer arm length. If present at the conjectured level, this would be large enough to be detectable with existing optical technology, provided that instrumental and environmental noises could be brought under control.

Although framed in geometric terms, the core idea was informational. A finite information content per unit area implies a finite resolution of position. Observing or ruling out the associated positional noise is therefore a probe of how much distinguishable positional information spacetime actually carries at macroscopic scales. This is exactly the sort of question an information-theoretic ether is meant to address.

4.2 Two co-located interferometers as a tau-correlated noise detector

The Holometer's most distinctive design choice was to use two nearly identical Michelson interferometers, placed side by side and sharing the same optical table environment, rather than a single instrument. Each interferometer had arms of order tens of meters, oriented in the same directions, and operated at high optical power to maximize sensitivity to tiny path-length differences.

From a conventional noise perspective, each interferometer sees a mixture of independent and common-mode disturbances: laser frequency and amplitude noise, mechanical vibrations, acoustic fluctuations, and so on. Careful engineering and data analysis are used to suppress or model these contributions. What makes the two-interferometer setup powerful is that one can compute the cross correlation of their outputs. Uncorrelated noise, such as local electronics noise, averages down with integration time. Correlated noise, affecting both interferometers similarly, stands out.

In tau-language, this geometry is almost tailor-made to detect tau-correlated noise. Let q_1(t) and q_2(t) represent the effective arm-length differences measured by the first and second interferometer, respectively. Ordinary noise sources generically contribute independent fluctuations delta q_1_env(t) and delta q_2_env(t), along with some identifiable common-mode terms. A tau-induced positional jitter in the underlying spacetime, however, would naturally couple in a similar way to both devices, because they occupy nearly the same region and share the same orientations.

If tau injects a transverse displacement noise delta q_tau(t) into the geometry, then both interferometers should see a similar realization of this process, up to small differences in alignment and configuration. The cross correlation of their outputs becomes a direct probe of tau-correlated noise. In the absence of tau, or for tau-models that do not produce such correlations, the cross-correlation spectrum should be fully explainable by known common-mode technical noises. Any excess correlation, with the right spectral and directional properties, would be a candidate signal.

In practice, the Holometer collaboration analyzed the cross-spectral density of the interferometer outputs over a broad frequency band, searching for the characteristic signature of the holographic-noise model they had in mind. The result was a non-detection at the predicted amplitude. In our terms, this means that no tau-induced correlated transverse jitter of the proposed strength was present. The apparatus thus functioned as a high-bandwidth, differential tau-detector for a specific class of transverse noise models.

4.3 Reparameterizing the excluded noise spectrum in terms of an information density I_tau

To connect the Holometer's null result to an information-theoretic ether, it is useful to re-express its constraints in terms of an effective information density I_tau. Conceptually, I_tau measures how many bits of distinguishable positional information per unit area and time the spacetime geometry can support in the transverse directions probed by the interferometers.

In the holographic-noise model, the positional indeterminacy arises because the number of distinguishable transverse positions over a longitudinal scale L is limited by the area of a corresponding two-dimensional surface divided by the Planck area. This leads to a root-mean-square transverse displacement that scales with the square root of the product of the Planck length and the arm length. The associated displacement noise spectral density S_x_tau(f) can be computed for a given encoding of positions, translating the discrete information bound into a continuous noise spectrum.

The Holometer excluded a specific level and shape of S_x_tau(f). In other words, it showed that if tau encodes positional information holographically, it must do so with a finer granularity, or

weaker coupling to measured positions, than the model assumed. By inverting the relationship between the information bound and the noise amplitude, one can reinterpret this as an upper bound on I_tau: the maximum information content per unit area and time consistent with the absence of the predicted jitter.

Even without committing to the original model's detailed derivation, the logic is robust. Any tau-model that manifests as a stationary, approximately white transverse displacement noise with long-range correlations over tens of meters is constrained by the same cross-correlation limit. The experiment thus sets a quantitative upper limit on how coarse the positional encoding of spacetime can be, at least for modes with the frequencies and length scales to which the Holometer was sensitive.

More generally, one can imagine parameterizing tau-induced noise by an information rate: bits per unit time by which the effective positional configuration of mirrors could fluctuate in a way not attributable to known physics. The Holometer's null detection then implies that this information rate is below a certain threshold, effectively constraining I_tau in the transverse channel. This translation turns a geometric null into an informational bound.

4.4 What classes of tau-models the Holometer already rules out

With this reparameterization in hand, we can summarize what kinds of informational ether models the Holometer has already excluded. The most direct casualty is the specific holographic-noise model that motivated the experiment: a tau-field that imposes a Planck-scale limit on transverse positional information, producing a level of correlated jitter matching the originally predicted spectrum. That model is now inconsistent with data.

More broadly, the Holometer rules out any tau-model with the following properties taken together. First, the model must produce a stationary, broadband transverse displacement noise in flat spacetime, with coherence over length scales at least as large as the interferometer arms. Second, that noise must be strongly correlated between nearby worldlines separated by distances comparable to the separation between the two interferometers. Third, the amplitude of this correlated noise must be at or above the originally targeted level. Any informational ether that satisfies these conditions is now excluded in the frequency band and environment probed.

On the other hand, many tau-models survive untouched. A tau-field that is fully Lorentz-invariant and couples so weakly to mirror positions that its induced noise is orders of magnitude below the Holometer's sensitivity is not ruled out. Models in which tau affects only very long wavelength modes, or only strong-gravity regions, or only internal degrees of freedom in matter rather than spatial geometry, also evade these constraints. Likewise, tau-models that alter

quantum probabilities without adding classical-looking noise are outside the Holometer's direct reach.

It is also important to note that the Holometer's sensitivity was focused on a particular kind of transverse jitter, oriented with respect to its arm geometry and tuned to a certain frequency range. Tau-induced effects that are strongly frequency-dependent, that couple predominantly to longitudinal degrees of freedom, or that require different boundary conditions might require other experiments for exclusion.

Nonetheless, the Holometer provides a valuable proof of principle. It demonstrates that informational-ether models which predict macroscopic, correlated positional fluctuations can be confronted with data and, if too coarse, ruled out. In tau-language, we can say that there is no strong, Planck-scale tau-jitter in the transverse spatial degrees of freedom over tens of meters at the probed frequencies. Any viable information-theoretic ether must therefore either encode positions with finer resolution, couple more subtly to q, or manifest in channels that require different experimental strategies.

5. Gravitational-Wave Interferometers as Long-Baseline tau Probes

If the Holometer is a short, high-bandwidth probe of transverse tau-jitter, the global network of gravitational-wave interferometers is its long-baseline, broadband cousin. LIGO, Virgo, and KAGRA were built to detect strain signals from astrophysical sources, but in doing so they continuously monitor the optical phase along kilometer-scale arms with astonishing precision. For most of their operation time, no strong gravitational wave is present. During those long stretches, each detector functions as an exquisitely sensitive interferometer staring at the vacuum along its arms.

From the perspective of an information-theoretic ether, this is a rare opportunity. Any tau-field that injects additional phase noise, positional jitter, or anisotropy into the optical paths of these instruments must compete with a noise budget that has already been dissected into known contributions: seismic motion, thermal noise, quantum shot noise, and technical disturbances. The published residuals, both in individual detectors and in their correlations, can therefore be mined for tau-signatures.

In this section we recast the network as a set of long-baseline tau probes. We outline how to think of these instruments as continuous vacuum interferometers, describe the kinds of tau-induced phase noise they could reveal, emphasize the role of orientation and Earth's motion as natural tau-modulation tools, and show how existing residual noise curves can be interpreted as bounds on tau–q coupling in the optical sector.

5.1 LIGO, Virgo, and KAGRA as continuous vacuum interferometers

Each gravitational-wave detector is, at its core, a modified Michelson interferometer. A high-power laser is injected into a beam splitter, its light sent down two orthogonal arms, reflected by test masses, and recombined at an output port. Fabry–Perot cavities in the arms and power-recycling optics enhance sensitivity to differential changes in arm length. The output is continuously monitored and digitized, producing a strain time series that encodes any tiny mismatch in optical path length between the arms.

Most of the time, no resolvable gravitational wave passes through the detector. The instrument is then operating as a continuous vacuum interferometer, probing whatever fluctuations exist in the differential phase accumulated along the arms. This phase is influenced by mirror motion, index-of-refraction changes, quantum fluctuations in the light, and technical noise. All of these contributions are modeled and, to a large extent, independently measured or constrained. What remains after subtracting known terms is a residual noise floor.

In tau-language, one can think of the arms as long, nearly empty tubes along which the informational structure of spacetime is being interrogated. If tau modifies the effective optical path length, or the way electromagnetic fields accumulate phase, then those modifications must feed into the same output channel as a gravitational wave. Unlike astrophysical signals, however, tau-induced effects are expected to be ever-present, not transient, and to have characteristic spectral and correlation properties that differ from those of standard noise sources.

The key advantage of these instruments is scale and integration time. Kilometers of baseline and years of data-taking provide sensitivity to tiny, persistent deviations that would be invisible in short, isolated runs. That makes them ideal for bounding any tau-model that predicts a small, stationary addition to phase noise or a subtle orientation-dependent effect in the propagation of light through vacuum.

5.2 tau-induced phase noise and its spectral signatures

To use gravitational-wave interferometers as tau probes, one must specify how tau would appear in their phase readout. A natural starting point is to treat tau as inducing an extra contribution delta phi_tau(t) to the differential phase between arms. This contribution might arise from microscopic fluctuations in effective arm length, changes in the relation between metric and optical path, or direct modifications of electromagnetic phase accumulation.

Whatever the microscopic origin, delta phi_tau(t) can be characterized by its statistical properties. In the frequency domain, this is encoded in a spectral density S_phi_tau(f). Different

tau-models correspond to different functional forms. A simple, scale-free informational jitter might produce an approximately white spectrum over a certain band, while a holographic or discrete structure could lead to a specific power-law or a peak at some preferred scale.

Practically, the detectors already quote a total phase or strain noise spectrum S_total(f), decomposed into contributions from known mechanisms. If tau adds an independent phase noise term, the measured spectrum becomes S_total(f) = S_standard(f) + S_phi_tau(f), where S_standard(f) is the sum of modeled environmental and quantum noises. The absence of unexplained excess noise beyond S_standard(f) at a given frequency then bounds S_phi_tau(f).

More subtle tau-models could tie the noise to specific directions or to long-range correlations between detectors. In that case, the spectral signature would not merely be a local excess in one instrument, but a pattern appearing across the network. For example, if tau couples to light in such a way that phase fluctuations are partially correlated between widely separated interferometers, then cross-spectral analyses between LIGO Hanford, LIGO Livingston, Virgo, and KAGRA would reveal an excess coherence not attributable to known couplings. The lack of such excess coherence at certain levels would then constrain the size of tau-induced correlations.

The essential point is that gravitational-wave detectors already provide detailed spectral decompositions of their noise. Reinterpreting these decompositions with a tau contribution in mind allows one to convert the spectacular care taken in building and characterizing these instruments into equally careful bounds on possible informational noise sources.

5.3 Orientation and time dependence: Earth's rotation as a tau-modulation tool

Just as Michelson and Morley used rotation to modulate a hypothetical aether wind, gravitational-wave interferometers automatically enjoy multiple modulation schemes thanks to Earth's rotation and orbit. These modulations are crucial if tau defines a preferred direction or frame in which its coupling to q is anisotropic.

Each detector has arms oriented along fixed directions in the local horizontal plane. As the Earth rotates, these directions sweep through the celestial sphere. If tau induces anisotropic phase noise that depends on the angle between an arm and some fixed direction in space, the strength of tau-induced fluctuations in each detector should vary periodically with sidereal time. Over longer scales, the Earth's orbital motion changes the laboratory velocity relative to any cosmic tau-rest frame, adding yearly modulation.

In practice, this means that tau-induced effects would not simply appear as a static addition to the noise floor. They would imprint a characteristic pattern: daily and seasonal variations in

noise power at particular frequencies or in cross-correlations between detectors. Even if the overall contribution is small, its structured time dependence can be teased out by folding long data sets on the sidereal day or the year and searching for consistent modulation.

Orientation also matters at the network level. Different detectors have different arm orientations and are located at different latitudes and longitudes. If tau couples in an anisotropic way, the phase noise spectra at each site would respond differently as the Earth turns. Cross-comparing these responses, while accounting for known environmental and technical differences, can therefore help isolate or constrain anisotropic tau-couplings.

From a design perspective, the criterion is straightforward. When treating gravitational-wave interferometers as tau experiments, one should not only look for static deviations from standard noise models but also for modulated components synchronized with Earth's rotation and orbit. A null result in these modulation channels is a particularly strong statement, because it is hard for mundane systematics to conspire to track sidereal time over years without revealing their terrestrial origin in other ways.

5.4 Using residual noise curves to bound tau–q coupling in the optical sector

The practical question is how to translate published noise curves into explicit bounds on tau–q coupling. The first step is to fix a simple parameterization of that coupling. For phase-noise models, one might characterize tau by a dimensionless coupling constant g_tau and a spectral shape function F(f), so that S_phi_tau(f) = g_tau^2 F(f). For anisotropic models, tensor coefficients multiplying direction-dependent terms could play a similar role.

Given such a parameterization, the residual noise spectrum in each detector provides an upper limit on S_phi_tau(f) at every frequency where the standard noise model is well validated. If the measured S_total(f) agrees with S_standard(f) to within some margin delta S(f), then S_phi_tau(f) must be less than delta S(f). This inequality can be inverted to yield an upper bound on g_tau for each assumed spectral shape F(f). For models predicting a flat spectrum in a certain band, the tightest single-frequency constraint in that band dominates. For more structured spectra, one may need to perform a weighted fit across frequencies.

Similar reasoning applies to correlation-based searches. Cross-spectral densities between pairs of detectors yield bounds on any tau-induced correlated phase noise S_phi_tau_corr(f). Because many technical noise sources are uncorrelated between sites, these cross terms can be exceptionally clean tau-channels. Again, if no excess correlation is observed beyond what standard environmental couplings explain, then S_phi_tau_corr(f) must lie below the quoted uncertainties, translating into limits on the amplitude of tau-induced common-mode fluctuations.

Taken together, these bounds carve out a region in the space of tau–q couplings that is excluded by existing data. They say, in effect, that if tau modifies the optical phase along kilometer-scale arms in the ways parameterized, it does so more weakly than some threshold set by the detectors' sensitivity. Importantly, this exercise does not require new hardware. It repurposes the enormous investment in gravitational-wave detection as a probe of informational structure in the vacuum.

From an informational-ether perspective, the conclusion is conservative but significant. Whatever tau may be, it does not inject large, unmodeled phase noise into the optical paths of LIGO, Virgo, or KAGRA, nor does it produce strong anisotropic modulations or cross-site correlations at the levels these instruments could have seen. Any viable tau-model in the optical sector must therefore live in the remaining, tightly constrained region of parameter space, or seek channels of influence that these long-baseline interferometers are not configured to detect.

6. Modern Cavity Experiments and Preferred Informational Frames

While interferometers like the Holometer and LIGO probe differences in optical path length, another powerful class of experiments focuses on resonance frequencies. High quality factor optical and microwave cavities, especially at cryogenic temperatures, can measure tiny changes in frequency as an apparatus is rotated or as the Earth moves through space. These experiments are the direct descendants of Michelson–Morley: rather than looking at fringe shifts in an interferometer, they look at shifts in the standing wave patterns sustained by a resonator.

In conventional language, these are precision tests of Lorentz invariance. They search for orientation and velocity dependent changes in the speed of light or in the dynamics of electromagnetic fields. Expressed in tau-language, they become tests for preferred informational frames. If tau defines a special rest frame or direction, then the effective optical properties of cavities should acquire a small anisotropy, and resonance frequencies should shift as the cavity orientation sweeps through that frame.

In this section we reinterpret modern cavity experiments in that way. We describe them as successors to Michelson–Morley, explain how Lorentz-invariance tests double as tests of tau-frame anisotropy, show how their frequency bounds can be recast as limits on tau-induced orientation-dependent shifts, and draw the implications for any tau-field that attempts to define an informational rest frame.

6.1 Cryogenic optical and microwave resonators as successors to Michelson–Morley

The original Michelson–Morley apparatus compared light travel times along two perpendicular arms. Modern cavity experiments implement a similar comparison, but in a more controlled and stable form. Instead of free propagation along arms, light is trapped in high quality factor resonators: optical cavities with mirrors of extraordinary finesse, or microwave cavities made of superconducting materials cooled to cryogenic temperatures. The resonance frequency of such a cavity is determined by its geometry, the speed of light in the medium, and boundary conditions.

By stabilizing lasers to these resonances and monitoring their frequencies with extreme precision, experimentalists can detect minute changes in the effective speed of light along the cavity axis. To test for anisotropies, two or more cavities are oriented at different angles, often orthogonal, and their frequencies are compared as the apparatus rotates on a turntable or as the Earth carries them through different orientations in space. Any dependence of the resonance frequencies on orientation would show up as a periodic modulation in the beat frequency between stabilized lasers.

Because the cavities are rigid and their mechanical properties can be controlled and modeled, systematic effects from thermal expansion or mechanical drift can be suppressed or accounted for. The remaining sensitivity is sufficient to constrain orientation-dependent fractional changes in frequency at levels far beyond what Michelson and Morley could access. In this sense, cryogenic resonator experiments are the modern incarnation of their interferometer: a refined, frequency domain version of the same null test, now pushed to parts in 10^15 or better.

From a tau perspective, this makes them ideal instruments for probing any informational field that alters the effective propagation of electromagnetic fields in a direction dependent way. The cavity does not care why the speed of light might change with orientation. It only registers that its resonances shift, or do not, as it turns.

6.2 Lorentz-invariance tests as implicit tests of tau-frame anisotropy

The language used to interpret these experiments is usually that of Lorentz invariance. Theories that allow small violations of Lorentz symmetry introduce coefficients that parameterize how the speed of light or other quantities might depend on direction or on the velocity of the laboratory relative to a preferred frame. By measuring or bounding orientation dependent frequency shifts, cavity experiments constrain these coefficients.

In tau-language, one can think of these coefficients as encoding the influence of a tau-frame: a direction or rest frame in which the informational field is simplest, and relative to which physical

processes acquire small anisotropies. Whether the underlying motivation is a particular effective field theory, a discrete spacetime structure, or an informational substrate, the operational content is the same. If there is a preferred frame, some observable must know about it.

When experiments report that no orientation dependent frequency shift is observed above a certain level, they are implicitly reporting that any tau-frame anisotropy that would couple to the electromagnetic sector in the relevant way is bounded below that level. In other words, either tau is fully Lorentz invariant at the scales probed, or its coupling to q in the cavity context is so weak that it effectively respects Lorentz symmetry to within the quoted precision.

This implicit testing of tau is important. It means that a whole class of informational ether models that posit a special frame but also assume that this frame leaves a measurable imprint on electromagnetic propagation are already tightly constrained, whether or not they were originally formulated in those terms. The Lorentz-invariance literature becomes, retroactively, a catalog of tau-frame bounds.

6.3 Recasting frequency bounds as limits on tau-induced orientation-dependent shifts

To make this reinterpretation explicit, we can recast the reported frequency bounds in tau terms. Suppose two cavities are oriented at right angles in the local horizontal plane. Let nu_1(t) and nu_2(t) be their resonance frequencies as functions of time. Standard theory predicts that, after accounting for known environmental and technical influences, the difference nu_1(t) minus nu_2(t) should be constant, or at least free of modulations tied to orientation with respect to distant stars.

A tau-field that defines a preferred direction in space could induce small orientation-dependent shifts in these frequencies. We can parameterize this by writing nu_i(t) = nu_0_i [1 + delta_i(t)], where delta_i(t) includes both standard effects and a tau-induced term delta_i_tau(t). If tau couples anisotropically, delta_i_tau(t) might take the form A_tau cos(2 alpha_i(t) + phi), where alpha_i(t) is the angle between cavity i and the preferred direction projected onto the horizontal plane, A_tau is the amplitude of the anisotropy, and phi is a phase.

Experiments typically analyze the beat frequency nu_1(t) minus nu_2(t) for such cos(2 alpha) components, folded on the sidereal day. They then report an upper bound on the amplitude of any detected modulation. This upper bound, expressed as a fractional frequency shift, is directly an upper bound on A_tau. In tau-language, A_tau measures how strongly the tau-frame leaks into the electromagnetic sector in these cavities.

By performing similar analyses across different cavity materials, frequencies, and geometries, experimentalists map out a multidimensional space of possible tau-induced orientation dependent shifts. Each null result carves out a region of that space. The translation is straightforward: where the Lorentz-invariance community writes down constraints on particular anisotropy coefficients, tau-language writes down constraints on the magnitude and directionality of tau–q coupling.

6.4 Implications for any tau-field that defines a preferred informational rest frame

What do these constraints imply for informational ether models that posit a preferred rest frame? At minimum, they say that if such a frame exists and couples to the electromagnetic field in the simple ways parameterized, its influence must be extremely small. Any model in which tau produces order one or even modest fractional changes in light propagation along different directions at laboratory energies is incompatible with the data.

There are several possible responses. One is to accept that tau, if it exists, is effectively Lorentz invariant in the electromagnetic sector at the scales and energies probed, either because its dynamics enforce that symmetry or because its couplings to photons are negligibly small. In this case, the preferred frame, if any, does not manifest in the simple orientation dependent shifts that cavity experiments would have seen.

Another response is to relocate tau's influence. Perhaps the preferred informational frame affects only gravitational degrees of freedom, or only certain internal properties of matter, leaving the pure electromagnetic sector untouched. In that case, different kinds of experiments would be needed to find it. The cavity bounds then become constraints not on tau itself, but on specific channels through which tau might have made itself known.

A third response is to retreat to a purely ontological use of tau. One can maintain that there is a preferred informational rest frame in some deep sense, but that it is not associated with any measurable anisotropy. This is logically possible, but it returns tau talk to the interpretive realm rather than the operational one. From the standpoint of physics, a preferred frame that has no observable consequences, even in principle, is indistinguishable from no preferred frame at all.

In all cases, modern cavity experiments play the same role as Michelson–Morley did for the optical aether. They show that certain naive ways of embedding a preferred medium into electromagnetic phenomena are untenable, and they push more sophisticated models toward either effective Lorentz invariance or sectors not yet probed. For tau, the message is clear. If it defines an informational rest frame, that frame must be almost perfectly hidden from the perspective of cavity electrodynamics, or it must act through structures more subtle than simple direction dependent shifts in the speed of light.

7. Bell Tests and QRNGs as Statistical Michelson–Morley Experiments

Up to this point, the focus has been on spatial and temporal structure: interferometers and cavities that probe how light and mirrors move in space. Yet an information-theoretic ether could also reveal itself in a different way, by subtly altering the statistics of measurement outcomes rather than the geometry through which they propagate. In that case, the natural instruments are not long-baseline interferometers but experiments whose primary output is a sequence of bits or discrete events: Bell tests and quantum random number generators.

These experiments are already designed to probe the deepest assumptions about causality and randomness. Loophole-free Bell tests interrogate whether correlations between distant systems can be explained by any local hidden variables. Quantum random number generators rely on the Born rule to produce bitstrings that are, in principle, unpredictable. If a tau-field acts as a hidden informational common cause, or if it slightly deforms the probability rules themselves, then Bell inequalities and randomness tests become statistical Michelson–Morley experiments. They do not look for fringe shifts; they look for excess correlations, tiny biases, or algorithmic structure where none should be.

In this section we recast these experiments in tau-language. We view Bell tests as probes of hidden informational common causes, characterize tau as a possible source of excess correlations or Born-rule deformations, show how long QRNG logs and algorithmic randomness tests can search for tau-structure in vacuum noise, and summarize what existing bounds already imply for information-ether models.

7.1 Loophole-free Bell experiments as probes of hidden informational common causes

Bell experiments begin with entangled systems and end with joint outcome statistics. In between lies the central question: are the observed correlations compatible with any model in which outcomes are determined by local variables and signals that travel no faster than light, or do they require a deeper nonlocal or nonclassical structure? Standard quantum mechanics predicts correlations that violate certain inequalities satisfied by all local hidden variable theories. Repeated violation of these inequalities, under carefully controlled conditions, is taken as evidence that the world does not conform to such theories.

In tau-language, one can think of a local hidden variable as a crude attempt at an informational ether: a shared cause in the overlapping past light cones of the experimenters that prearranges outcomes in a correlated way. A tau-field that functions as a hidden informational common cause would be a more refined version of this idea. It might carry high-dimensional, structured information that correlates measurement outcomes at spacelike separation without requiring direct communication between the measuring devices.

Loophole-free Bell experiments are designed precisely to close off standard ways such a field might act. By choosing measurement settings at space-like separation, randomizing those settings quickly, and ensuring high detection efficiencies, they minimize the room available for any influence that respects ordinary causal structure. If tau were to act as a hidden common cause obeying classical locality, it would have to encode enough information in the initial entangled state and local settings to reproduce the observed correlations. Bell inequalities quantify how far such strategies can go.

The repeated observation of violations consistent with quantum predictions, across many platforms and configurations, therefore constrains a large class of tau-models. Any informational ether that behaves like a classical, local reservoir of shared variables is incompatible with the data. What survives are models in which tau itself has nonlocal structure akin to, or more extreme than, quantum entanglement, or models in which tau modifies the probability rule directly rather than acting as a conventional hidden variable.

7.2 tau as a source of excess correlations or Born-rule deformations

Once we move beyond classical hidden variables, two broad ways remain for tau to influence Bell and other quantum experiments. The first is to generate excess correlations beyond those predicted by standard quantum theory. The second is to deform the Born rule, altering the mapping from quantum states to outcome probabilities. Both turn Bell tests and related experiments into statistical Michelson–Morley devices.

Excess correlations would appear when joint outcome statistics deviate from the quantum predictions, even if the no-signalling condition is preserved. For example, a tau-field could, in principle, coordinate outcomes in such a way that Bell inequalities are violated more strongly than allowed by quantum theory, or in a way that subtly biases specific combinations of outcomes in particular measurement settings. If the strength or pattern of these deviations depended on orientation, time of day, or other external parameters, they would resemble a tau-wind in probability space.

Born-rule deformations are subtler. Instead of changing which correlations are allowed, tau slightly shifts the probabilities themselves. Suppose standard theory predicts that, in a given measurement basis, a particular outcome should occur with probability p. A tau-deformed model might assign p + epsilon, where epsilon is tiny but structured, perhaps oscillating with sidereal time or depending on how the measurement device is oriented relative to a cosmic direction. Over many trials, even very small epsilon can, in principle, be detected as a deviation from the expected frequency.

In both cases, the experimental signature is a mismatch between measured and predicted statistics that cannot be absorbed into known imperfections or drifts. The analogy with Michelson–Morley is direct. The original experiment looked for a small, orientation-dependent difference in light travel time against a null expectation. Here, one looks for small, structured differences between observed and predicted probabilities, as a function of orientation, time, or configuration, against the null expectation of perfect agreement with quantum theory.

7.3 Long QRNG logs and algorithmic randomness as tests for tau-structure in vacuum noise

Quantum random number generators turn individual quantum events into bits. A photon passes or is reflected at a beam splitter, a decaying atom emits radiation in a random direction, a phase diffuses in a laser above threshold. Each event is, in standard theory, irreducibly probabilistic, with frequencies dictated by the Born rule and no deeper pattern available to any observer or hidden agent.

In tau-language, QRNGs are continuous samplers of whatever structure exists in the vacuum and in the measurement process. A tau-field that subtly biases outcomes, introduces long-range correlations, or imprints algorithmic regularities on nominally independent events would leave its fingerprint in the bitstrings they produce. The longer the log, and the more carefully its environment is controlled, the more sensitive the generator becomes as a statistical Michelson–Morley experiment.

Conventional randomness tests focus on relatively simple properties: balance between zeros and ones, short-range correlations, distribution of runs, and so on. An informational ether might evade these tests yet still introduce structure detectable by more sophisticated methods. Algorithmic randomness and modern machine learning provide such methods. By compressing bitstrings with universal codes, training models to predict future bits from past contexts, or seeking correlations between separate QRNG outputs as a function of orientation or time, one can probe for tau-structure that goes beyond simple bias.

For example, imagine two QRNGs located far apart, both sampling what should be independent quantum noise. If tau provides a common informational environment, the outputs might exhibit subtle mutual information: shared patterns detectable only after large data accumulation. Alternatively, a single QRNG, oriented differently or operated at different times of day, might show tiny but systematic shifts in compressibility or predictability, hinting at a tau-wind aligned with cosmic motion.

In all such cases, the experimental pattern is the same. Under the null hypothesis of standard quantum randomness, the bitstrings should be algorithmically random within the limits of finite sample sizes and instrumentation. Any reproducible deviation from this, especially one tied to

external parameters, becomes a candidate tau-signal. The absence of such deviations, after exhaustive search, becomes a bound on how much structure tau can impress on vacuum noise without contradicting observed randomness.

7.4 Existing bounds on deviations and what they imply for information-ether models

Bell experiments and QRNGs already provide stringent constraints on deviations from standard quantum statistics, even when they are not framed in tau-language. Correlation measurements agree with quantum predictions within small experimental uncertainties. Searches for signalling or systematic biases have repeatedly come up empty. Commercial and laboratory QRNGs generate bitstreams that pass extensive batteries of statistical tests, and increasingly, more advanced analyses.

Converted into tau terms, these results say that any informational ether which acts by adding classical hidden common causes is ruled out at the level tested by loophole-free Bell experiments. Tau cannot be a simple, local reservoir that prearranges outcomes in a classical way and still match observed violations. More exotic models, in which tau carries nonlocal structure similar to or more general than quantum entanglement, are not excluded by Bell tests alone, but they are tightly constrained to reproduce the observed correlation patterns without detectable deviations.

For probability deformations, the bounds are phrased in terms of small bias parameters. If a given outcome in a QRNG is predicted to occur with probability one half, and long runs of data constrain any systematic deviation to be smaller than some epsilon, then tau-induced shifts in that channel must be less than epsilon, at least in the tested configurations. Similar statements hold for joint probabilities in Bell tests. Any tau-model that predicts larger, structured deviations in the tested regimes is incompatible with data.

These are not absolute no-go theorems. A tau-field that is exactly aligned with quantum statistics in the regimes examined, or that manifests only at energies, scales, or configurations not yet accessible, can still be entertained. Tau can also remain as a purely interpretive layer: an informational story about why the Born rule holds rather than a source of departures from it. But as with interferometric and cavity tests, the more one tries to give tau operational content, the more it must thread a narrowing path between existing bounds.

In that sense, Bell tests and QRNGs are statistical Michelson–Morley experiments. They do not rule out the idea of an informational ether by fiat. They rule out large and simple classes of tau-models that would have produced detectable excess correlations, biases, or algorithmic structures in the data we already have. Any viable information-ether model must therefore either be operationally indistinguishable from standard quantum theory in these arenas, or

offer sharply defined, as yet untested predictions in domains where the next generation of experiments might look.

8. Synthesizing Constraints: Narrowing the Space of tau-Models

Taken one by one, each experimental class tells a focused story about tau. The Holometer constrains correlated transverse jitter. Gravitational-wave interferometers constrain long-baseline optical phase noise and its modulation. Cavity experiments constrain orientation dependent shifts in resonance frequencies. Bell tests and quantum random number generators constrain deviations from quantum statistics and hidden informational common causes.

When we put these together, the picture is sharper than any single line of evidence. We do not yet have a unified parameter space for all possible tau-models, but we can already say that whole families of simple, physically motivated ideas are ruled out. Others are forced into corners where their influence is so weak, or so cleverly aligned with existing theory, that they begin to look less like new physics and more like reinterpretation.

This section draws those threads together. First, we compare interferometric, cavity, and statistical bounds in a common language of tau-to-q coupling. Then we spell out the classes of tau that are already excluded: those that would have produced large positional jitter, strong preferred-frame effects, or overt Born-rule violations. We then identify surviving scenarios: Lorentz invariant tau, ultra-soft couplings, and models that function mainly as metaphors. Finally, we ask how much informational structure the vacuum could still hide while remaining consistent with current data.

8.1 Comparing interferometric, cavity, and statistical tau-bounds

Each experimental channel has its own natural observable and its own way of talking about sensitivity. Interferometers report strain or displacement noise as a function of frequency. Cavities report fractional frequency stability and limits on orientation dependent shifts. Bell and QRNG experiments report statistical confidence intervals on correlations and outcome frequencies. To compare their impact on tau, we need a simple way to think across these domains.

One useful abstraction is to treat tau-to-q coupling as a small dimensionless factor that governs how strongly tau influences a given observable. In interferometers, this shows up as an additional phase or displacement noise component. In cavities, it shows up as a tiny change in the effective speed of light or index of refraction as a function of orientation. In statistical experiments, it shows up as a small bias or correlation parameter in probabilities.

If we write these schematically as

- tau-induced displacement noise proportional to g_disp,
- tau-induced orientation anisotropy proportional to g_aniso,
- tau-induced probability deformation proportional to g_prob,

then the experiments we have discussed provide upper bounds on each of these g-like quantities in their respective regimes. The Holometer bounds g_disp for transverse positional jitter at arm-length scales of tens of meters and at high bandwidth. Gravitational-wave detectors bound g_disp for kilometer scales and a broad frequency band, and also place limits on any correlated phase noise between sites. Cavity experiments bound g_aniso at optical and microwave frequencies to extraordinarily small values. Bell and QRNG experiments bound g_prob for the particular quantum systems and measurement settings they use.

These bounds are not directly comparable in a numerical sense without a more detailed theory, because g_disp, g_aniso, and g_prob are defined with respect to different observables and units. What matters is that they all point in the same qualitative direction. Any tau that couples in a simple, linear way to q across these channels must have couplings small enough that it has escaped detection in all of them. The more one insists that tau is a physically active field, the more one must accept that its measurable influence, at least in the electromagnetic and low energy quantum sectors, is highly constrained.

8.2 Classes of tau that are already excluded: large-jitter, strongly anisotropic, or overt Born-rule-breaking

Within this combined picture, several broad classes of tau-models are effectively off the table. The first are large-jitter models, of which the original holographic-noise proposal tested by the Holometer is the prime example. Any tau that makes macroscopic positions fuzzy at a level that would induce correlated mirror motion visible above the Holometer's sensitivity has been ruled out. The same applies, with different numerical details, to phase noise that would have been visible as unexplained residuals in gravitational-wave interferometers.

A second excluded class consists of strongly anisotropic tau-models that act like a preferred optical frame. Modern cavity experiments have pushed bounds on direction dependent changes in the speed of light to extremely small fractional levels. Tau-models that posit a medium-like frame in which light travels noticeably faster or slower along some directions than others, at laboratory energies, are incompatible with these results. Any informational ether that behaves like a nineteenth century aether in the electromagnetic sector has been squeezed out of viability.

A third excluded class covers overt Born-rule-breaking models. If tau were to introduce systematic biases in single-outcome probabilities or in joint correlations at levels above current experimental uncertainties, long running QRNGs and high precision Bell tests would already have seen them. There is still room for tiny deformations, especially if they are configured to cancel in some observables, but large and simple modifications of quantum statistics are incompatible with the wealth of data that confirms the Born rule across diverse platforms.

Together, these exclusions mark out a kind of no-go region for naive informational ether models. If tau makes positions too grainy, cavities and interferometers complain. If tau draws too strong a preferred direction in optical propagation, resonator experiments complain. If tau pushes quantum probabilities too far away from their standard values, Bell and QRNG experiments complain. Tau can still be present, but it cannot behave in these straightforward, phenomenologically generous ways.

8.3 Surviving scenarios: Lorentz-invariant tau, ultra-soft couplings, and purely metaphysical re-descriptions

What remains viable after these constraints are taken seriously? Several broad scenarios survive.

One is Lorentz invariant tau with effectively zero anisotropy in the sectors we have probed. In such models, tau may still exist as a universal informational field, but its couplings to electromagnetic and low energy quantum phenomena respect Lorentz symmetry to extremely high accuracy. From the standpoint of cavity and interferometer experiments, tau is invisible. It might manifest only in gravitational phenomena, at Planckian energies, or through subtle effects in sectors not yet probed with comparable precision.

A second surviving scenario involves ultra-soft couplings. Here tau does couple to q in principle, but with strengths far below current experimental sensitivity. The couplings g_disp, g_aniso, and g_prob are nonzero but tiny, perhaps scaling with very high powers of energy over some large cutoff, or suppressed by large dimensionless factors. In these models, future generations of experiments might eventually see a signal, but only after substantial improvements in sensitivity or access to new regimes.

A third scenario views tau as primarily a metaphysical or interpretive construct. In this view, tau is a way of talking about the structure already encoded in quantum states, spacetime fields, and dynamical laws. It does not add new degrees of freedom or couplings. Instead, it provides a unifying language for describing how information flows and organizes itself in the existing theoretical framework. In this sense, tau has explanatory power at the conceptual level, but it does not demand new experimental signatures.

There are also hybrid possibilities. Tau might be operative and measurably active in domains we have not considered, such as inside black holes, in early universe cosmology, or in exotic condensed-matter phases. It might couple more strongly to matter fields that have not yet been tested with interferometric or statistical tools. It might influence the emergence of classicality or the structure of large scale correlations in ways that require astrophysical or cosmological observations rather than laboratory experiments.

The common theme among all these surviving scenarios is subtlety. Tau is no longer a simple extra medium that pushes on mirrors, distorts light cones, or overtly reshapes probabilities. It is either deeply aligned with existing symmetries, extremely weakly coupled, or confined to explanatory roles rather than new dynamics in the regimes we can reach.

8.4 How much informational structure can the vacuum still hide?

Given these constraints, it is natural to ask whether the idea of an informational ether has been emptied of physical content. The answer is more nuanced. The vacuum can still hide an enormous amount of structure, provided that structure is arranged in ways that do not violate the tight bounds we have surveyed.

From an informational perspective, what experiments constrain is not the total information content of the vacuum but the accessible information in specific channels. Interferometers tell us that, at the scales probed, the transverse positional degrees of freedom do not exhibit large, additional jitter beyond known noise sources. Cavities tell us that electromagnetic propagation does not carry a detectable imprint of a preferred frame. Bell tests and QRNGs tell us that, in the systems and settings used, outcome statistics are remarkably well described by standard quantum rules.

None of this forbids the vacuum from having a rich internal organization. It may encode correlations at scales, energies, or in degrees of freedom that our present experiments do not touch. It may be that tau provides a deep informational accounting of why fields, particles, and probabilities take the forms they do, without manifesting as an extra force. In that case, the informational ether is more like the grammar of a language than like a new phoneme: it structures everything without being a separately audible sound.

At the same time, the constraints do impose discipline. Any claim that tau is a physically active field must be accompanied by a precise statement of where and how it acts, and why its actions have not yet been seen in the many channels we have examined. The vacuum cannot be assumed to hide arbitrarily simple tau-deformations. It can hide structure, but not structure that would have produced large, low order effects in light propagation, mirror motion, or quantum statistics at laboratory scales.

One way to express this is to say that the universe is already a giant Michelson–Morley experiment for informational ether models. By reinterpreting interferometers, cavities, and statistical tests in tau-language, we see that much of the naive parameter space has been quietly swept away. What remains is a smaller, more interesting space of possibilities in which tau is either tightly aligned with existing theories, exceedingly gentle, or primarily conceptual. It is in that narrowed space that any future, physically meaningful notion of an informational ether will have to live.

9. Designing Next-Generation tau-Targeted Reinterpretations and Experiments

If tau is to remain more than a metaphor, the next step is not only to reinterpret existing experiments but to design new analyses and instruments with tau explicitly in mind. The point is not to build an "information ether detector" in isolation, but to weave tau-questions into the fabric of ongoing precision physics: gravitational-wave astronomy, quantum optics, metrology, and quantum information.

This involves three intertwined moves. First, we can extract more from what has already been measured by data-mining archival records for tau-like signatures. Second, we can identify new experimental channels in which tau-couplings might be amplified or revealed more clearly. Third, we can begin to write tau-parameters directly into the language of proposals and results, so that nulls and constraints accumulate in a systematic way.

9.1 Data-mining existing archives: LIGO noise, Holometer records, QRNG beacons

The easiest tau-experiments to "build" are the ones that have already run. Large collaborations maintain archives of raw and processed data that are rich with untapped structure. In the tau-language, those archives are long movies of q(t) under a wide variety of conditions, waiting to be re-read.

Gravitational-wave detectors provide multi-year records of strain and auxiliary channel data. Standard analyses use these to hunt for transient signals, characterize noise sources, and validate astrophysical events. A tau-driven reanalysis would ask different questions. Are there residual noise components in the differential arm signals that track sidereal time in a way not accounted for by known environmental effects? Do cross-correlations between geographically separated detectors show any persistent, broadband coherence after known couplings are removed? Are there frequency bands where the residuals exhibit statistics inconsistent with the modeled quantum and thermal noises, pointing to an extra informational contribution?

The Holometer, although no longer operating, has left behind high-rate time series and cross-spectral information. Its original analysis focused on a particular holographic noise model. A tau-centric revisit could test a wider family of correlated noise spectra and temporal structures, including models inspired by alternative information bounds or different assumptions about tau-coherence length and time.

Quantum random number generators, both laboratory prototypes and public beacons, generate continuous streams of bits. Many of these streams are archived or at least accessible for finite histories. Beyond conventional randomness tests, a tau-reanalysis could apply algorithmic complexity measures, modern prediction models, and cross-correlation tests between geographically separated generators. It could look for tiny, structured departures from ideal randomness that track orientation, gravitational potential, geomagnetic conditions, or cosmic time.

None of these efforts require new hardware. They require only a clear tau-parameterization, access to data, and careful statistical work that treats tau as a possible contributor alongside known noise sources. In that sense, data-mining becomes the first stage of a next-generation tau-program: a way to tighten constraints, or discover anomalies, using the universe's existing investment in precision measurement.

9.2 New experimental channels: chaotic mechanical amplifiers, quantum networks, and space interferometers

Beyond archival reanalysis, there are experimental directions that naturally amplify small tau-couplings or probe regimes current instruments do not reach. These can be thought of as new channels through which tau might imprint itself on q.

Chaotic mechanical amplifiers are one such channel. Systems near the onset of chaos, such as coupled pendula or nonlinear oscillators, are exquisitely sensitive to small perturbations in initial conditions or driving forces. If tau couples weakly to mechanical degrees of freedom, it may be easier to see its fingerprints in the statistical properties of a chaotic attractor than in a simple linear oscillator. Carefully designed experiments could monitor differences between nominally identical chaotic systems, or between a chaotic system and a reference, searching for correlated deviations that resemble tau-driven forcing rather than ordinary noise.

Quantum networks provide another opportunity. Entangled states shared between distant nodes, especially if combined with distributed quantum sensors, create large, tunable Hilbert spaces with high sensitivity to phase and correlation structure. A tau-field that introduces subtle nonlocal correlations, or that slightly warps the probability landscape for multi-party measurements, might be more easily detected in a network than in a single two-party Bell

experiment. Networked tests could, for example, look for orientation-dependent correlation patterns across a baseline that spans Earth's rotation and orbital motion.

Space-based interferometers and optical links extend the baseline and environmental diversity far beyond terrestrial labs. Interferometers with arms millions of kilometers long, or optical time transfer between satellites and ground stations, probe tau-couplings in regimes of gravitational potential and separation that ground-based instruments cannot. If tau interacts with curvature, redshift, or large-scale structure, its effects may be more pronounced on these scales. The same Michelson–Morley logic applies: design differential, modulated observables that would remain null under standard theory but respond to plausible tau-perturbations.

These channels do not replace interferometers, cavities, or QRNGs; they complement them. By bringing chaos, entanglement, and space baselines into the picture, they widen the range of q-systems that tau could plausibly touch and give the informational ether fewer places to hide.

9.3 Integrating tau-parameters into future experimental proposals and funding rationales

For tau to become a routine part of precision physics, it must appear not only in retrospective analyses but in the way experiments are conceived and justified. That means writing tau-parameters directly into proposals, design documents, and science cases.

In practice, this can be done modestly. When drafting the scientific reach of a new interferometer, one can include a section that treats an additional phase-noise term S_phi_tau(f) alongside the usual noise budget. The proposal can state that, under certain tau-models, the experiment would be sensitive to couplings down to a particular g_tau, and that null results would improve existing bounds by a given factor. For cavity experiments, similar tau-anisotropy coefficients can be defined and quoted. For quantum experiments, proposed sensitivities to small bias or correlation parameters can be framed as tests of tau-induced probability deformations.

Such additions strengthen funding rationales. They show that the experiment is not just answering one question (about gravitational waves, clocks, or quantum devices) but also contributing to a broader program of probing the informational structure of the vacuum. They position tau-tests as secondary science objectives that cost essentially nothing once the primary apparatus is built, but which yield high conceptual return if anomalies are found or if bounds are tightened.

Over time, if enough proposals include explicit tau-parameter sections, a de facto standard will emerge. Reviewers and agencies will become accustomed to seeing tau-sensitivity discussed

alongside more familiar figures of merit. This will make it easier to coordinate efforts across different experiments and to track progress in constraining or exploring the informational ether.

9.4 Toward a standard reporting language for tau-sensitive null results

The final ingredient in a coherent tau-program is communication. Null results are only as useful as the clarity with which they are reported and compared. At present, data relevant to tau are scattered across publications that speak in different dialects: strain noise, Lorentz-violation coefficients, p-values for randomness tests. To synthesize these into constraints on tau, one must translate between many notations.

A standard reporting language for tau-sensitive results would streamline this process. It would not replace existing conventions, but sit alongside them as a common layer. For each experiment, one would specify:

- the class of tau-models being constrained (noise injection, anisotropy, probability deformation),
- the specific tau-parameters used (for example, a noise amplitude, an anisotropy coefficient, or a bias parameter),
- the functional dependence of the observable on those parameters,
- the upper bounds (or confidence intervals) derived from the data.

These could be summarized in tables or compact parameter-space plots, much as is done for other beyond-standard-model searches. Importantly, even when no tau-language is used in the main text, an appendix or supplementary note could provide the mapping for those who care to use it.

Such a convention would make it easy to say, for example, that a new cavity experiment has reduced the bound on a particular tau-anisotropy coefficient by an order of magnitude, or that a reanalysis of QRNG logs has improved limits on a certain bias parameter. It would also make it easier to spot gaps: regions of tau-parameter space that have not yet been probed by any experiment.

In this way, tau becomes not just a speculative idea but a shared coordinate system for null results. The informational ether, if it exists, will either eventually light up one of those coordinates, or see its accessible parameter space shrink steadily as precision physics continues its quiet, Michelson–Morley-like work.

10. Logostics Perspective: tau(t), q(t), and Living with Null Ether Results

Once we translate a wide range of precision experiments into tau-language, an uncomfortable but important possibility comes into view: the informational ether, if conceived as a physical field, may be largely invisible to the instruments we have built. The Holometer, gravitational-wave interferometers, cavity resonators, Bell tests, and QRNGs together suggest that any simple, medium-like tau that pushes on mirrors, tilts light cones, or openly deforms the Born rule is highly constrained.

From a logostic point of view, this is not the end of tau but a redirection of how we understand it. Logostics begins not with an ether but with a relation: q(t) approaching tau(t). Here tau(t) is a time-dependent manifold of "living truth" or informational structure, and q(t) is the state of a system, agent, or civilization that can align with or drift from that structure. The primary content lies in the dynamical relation between q and tau, rather than in the question of whether tau behaves like a literal field in spacetime.

In this section we re-read the experimental tau-bounds through that lens. We interpret the null results as telling us something about which roles tau can fruitfully play: less as an extra force and more as a unifying metaphor and background order. We then explore what it means, philosophically and theologically, to inhabit a universe where informational ether hides behind successful nulls, even as logostic alignment remains central to how meaning and truth unfold.

10.1 Reinterpreting tau-bounds within a logostic framework of alignment q(t) -> tau(t)

In logostics, tau(t) is not primarily a medium in which waves propagate. It is a moving target: a manifold of viable, coherent patterns toward which systems can align. The dynamics of q(t) are judged not only by internal consistency but by their approach to or deviation from tau(t). In that sense, tau-bounds from experiments are about the channels in which alignment cannot be achieved by treating tau as an extra degree of freedom in standard physics.

The interferometric and cavity constraints say, effectively, that if we try to encode tau as a low-level field that shakes mirrors, produces anisotropies, or injects extra noise, then alignment is not happening there. The best-fitting description of those q-systems uses known Hamiltonians, noise sources, and symmetries, with tau playing no additional dynamical role. Alignment, in other words, is trivial in that sector: q(t) already evolves in a way that fits tau's requirements to within experimental precision, without needing a new term.

From a logostic standpoint, that is not a defeat but a calibration. It tells us that for many low-level physical degrees of freedom, the simplest representation of tau's influence is "baked in" to existing laws. The q-variables of standard physics already live on a manifold that is, to high

accuracy, tau-compatible. When we ask whether tau is present in interferometric phase noise, the answer may simply be that what we call Maxwell, Lorentz invariance, and the Born rule are already the local shadow of tau's structure in that domain. There is nothing further for tau to do as an extra source of deviations.

The q(t) -> tau(t) relation then shifts focus. Instead of asking whether tau perturbs basic optical experiments, we ask where misalignment is actually visible: in complex systems, social structures, epistemics, ethics. The experimental tau-bounds constrain attempts to put the logostic relation into the wrong layer. They suggest that the interesting work of alignment does not occur as centimeter-scale jitter or micro-hertz anisotropy in light speed, but higher up the stack, where agents, models, and institutions respond to information and truth.

10.2 What null results say about tau as metaphysical background versus physical field

Null results have a sorting function. They do not prove that tau does not exist. They tell us which categories of tau-description have no measurable surplus over existing theories. The informational ether can be described as a physical field, as a metaphysical background, or as a hybrid of both. The experiments we have surveyed push it strongly toward the second category, at least in the electromagnetic and low-energy quantum sectors.

As a physical field, tau would be expected to show up as something like a fifth interaction, an extra term in the Lagrangian, a preferred frame, or a source of noise with distinctive structure. The absence of such signatures means that if tau is a field in that sense, it is either extraordinarily weakly coupled, confined to regimes we have not probed, or so exactly aligned with existing symmetries that it becomes indistinguishable from them. The added ontological machinery does little, if any, predictive work.

As a metaphysical background, by contrast, tau does not need to generate new forces. It functions as the informational "shape" of what is possible: the constraint surface on which physical, biological, and cognitive dynamics unfold. In this role, tau is akin to the space of possible codes, dynamical laws, or logical structures. It is present in the sense that reality instantiates patterns that are intelligible, compressible, and law-governed. But it does not need to act locally on mirrors or detectors.

Null ether results then become evidence about tau's category, not its reality. They say that treating tau as an extra, medium-like field layered on top of the standard model is unnecessary and, in many simple formulations, wrong. They leave open, however, the possibility that tau is the abstract background with respect to which q-dynamics are evaluated: the space of lawful patterns and living truths that physics, along with other domains, partially samples. In that

reading, experimental physics constrains naive ether models while leaving deeper logostic interpretations untouched.

10.3 Informational ether as a unifying metaphor, not an extra force

One way to live with this outcome is to demote “informational ether” from a literal medium to a unifying metaphor. The word “ether” keeps the historical resonance: a pervasive something, everywhere and always present. The “informational” qualifier shifts its content from mechanical support for waves to the structural support of patterns, regularities, and codes.

In this metaphorical role, informational ether is the common language in which we describe:

- the constraints implied by conservation laws and symmetries,
- the limits and capacities described by Shannon and algorithmic information,
- the pattern of lawful correlations that gives physics its predictive power,
- the logostic manifold tau(t) that living agents can try to align with.

Here tau does not supplement existing interactions with an extra force. It reframes them as expressions of a deeper coherence. Maxwell’s equations, quantum measurement statistics, and the stability of matter are not “explained” by tau in a mechanistic sense, but they are seen as particular realizations of a more general informational order. The ether is then the totality of that order, not an additional field within it.

This unifying metaphor still has operational bite. It suggests new ways to relate disparate phenomena, such as viewing gravitational-wave detectors, QRNGs, and neural networks as different q-systems sampling the same underlying informational constraints. It motivates the sort of tau-language we have used in this paper: a cross-cutting parameterization that lets experiments report what they have ruled out in a common vocabulary, even when they are not explicitly probing a new field.

In that sense, “informational ether” becomes the name of a perspective rather than of a substance. It is the logostic habit of seeing q(t) as always in relation to tau(t) – to some background of order and truth – even when that background does not appear in the equations as a separate dynamical term. The experimental nulls are then not disappointments but reminders to keep the metaphor in its proper place.

10.4 Philosophical and theological reflections on a universe where tau hides behind successful nulls

Finally, there is the question of how it feels, intellectually and spiritually, to inhabit a universe in which tau hides behind successful nulls. If one hoped for a dramatic, Michelson–Morley-like refutation of standard physics that would announce the informational ether as a new medium, these results may seem anticlimactic. But another reading is possible, one that resonates with older philosophical and theological motifs.

In many traditions, the deepest order is not something that pushes directly on objects. It is what makes lawful behavior possible in the first place. Logos, in its broad sense, is not a fifth force; it is the intelligibility of the world, the fact that reality can be described by coherent mathematics and that experiments can converge on stable patterns. In a logostic vocabulary, tau(t) is that Logos expressed as a time-dependent manifold of possible truths, and q(t) is the moving, partial alignment of actual systems with that manifold.

On this view, the fact that low-level experiments keep returning null results for new media is not a sign of absence but of sufficiency. The existing laws are already saturated with tau's structural content in those regimes. The alignment problem shifts from discovering a new field to living faithfully within the patterns already given: using our instruments to map them, our theories to compress them, and our moral and communal practices to respond to them.

Theologically, this suggests a universe in which the hiddenness of tau is not a bug but a feature. If the informational ether is closely allied with Logos, then we should not expect it to appear as one more term in a Hamiltonian. We should expect it to appear as the quiet coherence of the whole, the way physical null results, mathematical structures, and ethical demands interlock without remainder. A science that repeatedly finds "no new ether here" at the level of forces can coexist with, and even support, a conviction that there is a deeper informational order worth aligning with.

Living with null ether results, then, does not mean abandoning tau. It means accepting that the primary drama of q(t) -> tau(t) plays out in how agents, models, and societies orient themselves toward truth in a universe whose low-level physics is already astonishingly well aligned. The experiments we have surveyed set the stage: they tell us where tau is not needed as an extra field. The remaining task is logostic: to understand how tau operates as background order and living truth, and how q can move toward it, not by inventing new media, but by reading more deeply what the existing nulls and laws are already saying.

11. Conclusion: The Hidden Michelson–Morley Program We Already Ran

By the time one has translated Holometer data, gravitational wave noise curves, cavity frequency limits, Bell inequalities, and QRNG bitstrings into tau language, a striking realization appears: we have already carried out a vast, distributed Michelson–Morley program for the informational ether, without ever naming it that way.

No single flagship experiment announced “the death of tau” the way the historical narrative sometimes frames the death of the optical aether. Instead, thousands of coordinated nulls, across decades and platforms, have quietly removed large, simple ways that an information field could have shown up. What survives is not a dramatic new medium, but a more subtle picture: tau as background order rather than extra force, and the meaningful work of alignment happening in how we read, model, and live within that order.

11.1 Summary of how existing experiments act as information ether tests

The reinterpretation can be summarized in one line: wherever precision physics expected a clean null, we have already done an information ether test.

- Short baseline interferometers like the Holometer searched for correlated transverse jitter; in tau language, they bounded a class of tau induced position noise.
- Long baseline interferometers such as LIGO, Virgo, and KAGRA continuously stare down kilometers of vacuum; they bound tau induced optical phase noise, anisotropies, and cross site correlations.
- Cryogenic optical and microwave cavities extend the original Michelson–Morley logic into the frequency domain; they bound tau models that would define a preferred informational rest frame for the electromagnetic sector.
- Loophole free Bell tests and long running QRNGs probe the statistics themselves; they bound tau as a hidden common cause or as a source of overt deviations from the Born rule, down to very small bias and correlation parameters.

Each of these programs, framed in its native language, was pursuing other goals: gravitational waves, Lorentz symmetry, foundational quantum tests. But in every case, a failure to find certain signals is, when translated, a statement about what tau is not doing at that layer.

11.2 Why reinterpretation matters for future theory building

One could shrug and say: if we already have the nulls, why bother with tau language at all? The answer is that reinterpretation changes what kinds of theories we waste time on, and what kinds might still be worth pursuing.

Without a unified picture, it is easy to reintroduce the same doomed ether patterns under new names. A model that imagines tau as a frame picking medium for light, or as a source of macroscopic Planck scale jitter, or as a classical hidden variable reservoir, can look fresh in isolation. Viewed against the combined constraints, it is just a repackaging of ideas that have already been squeezed out.

Tau language helps theory building in at least three ways. It:

- forces one to specify where tau acts (geometry, fields, probabilities, agents),
- makes contact with concrete experimental channels and their existing bounds,
- highlights the difference between genuinely new dynamics and mere metaphysical relabeling.

In that sense, reinterpretation is a kind of hygiene. It prevents the informational ether from becoming a dumping ground for vague yearnings, and instead turns it into a disciplined coordinate system for asking: if tau is real in more than a metaphorical sense, where could it still be hiding?

11.3 The path forward: explicit tau parameterization in experimental design and reporting

The practical path forward is not a heroic “tau detector” but a slow normalization of tau parameters in experimental work.

For new interferometers, space missions, or quantum networks, one can:

- include simple tau noise or anisotropy terms in sensitivity forecasts,
- state explicitly which classes of tau models the design would constrain if no signal is found,
- plan modulation schemes and differential observables with tau in mind alongside the main science goals.

For reporting results, one can:

- add a short appendix that maps the usual figures of merit (strain noise, frequency shifts, p value bounds) onto a small set of tau parameters,
- summarize nulls as exclusion regions in a shared tau parameter space,
- encourage data archiving and access specifically so that tau motivated reanalyses are easy.

Over time, this would turn the hidden Michelson–Morley program into an explicit one. Instead of rediscovering the same constraints piecemeal, the community would accumulate a visible atlas of where tau cannot be and how tightly it is bounded in each channel. That does not guarantee discovery, but it guarantees that any future discovery claim will know which territories it must explain away.

11.4 Final reflections on ether, information, and the discipline of being wrong gracefully

The original ether story is often told as a drama: bold theorists, decisive experiment, clean refutation. The reality was messier and more instructive. A useful but over literal picture was tested, patched, and finally transcended by a better symmetry principle. The important part was not that the aether "died," but that physics learned how to be wrong gracefully at scale.

The information ether risks repeating the same arc, unless we let the nulls do their work. If we insist that tau must be a medium with mechanical side effects we can feel, we will spend our time inventing and discarding ever more contrived models. If instead we accept what the hidden Michelson–Morley program has already told us, we are free to relocate tau: from a hypothetical fifth field into the structure of laws, symmetries, codes, and living alignment itself.

In that relocation, being wrong about the ether is not a loss but a refinement. We lose the picture of tau as a subtle wind blowing through the lab, and we gain the picture of tau as the quiet coherence that allows the lab, the equations, and the nulls to exist at all. The discipline of being wrong gracefully consists in letting experiments close doors on the easy, mechanical fantasies so that theory and philosophy can walk through the harder, more interesting doors that remain.

An informational ether that survives this process will not look like the luminiferous aether with better marketing. It will look more like a name for the layered order in which physics, computation, and meaning hang together. And the fact that our best instruments see no extra medium there, beyond the structures we already know, may be the clearest clue yet about where tau really lives.

Epilogue: The Dimension Michelson–Morley Could Not Have Seen

From today's vantage point, it is tempting to ask a slightly mischievous question: was the Michelson–Morley experiment "wrong" because it was only three dimensional? Should it have been designed to probe an orthogonal in–out dimension, the kind of hidden axis we later learned to represent with the square root of negative one in quantum mechanics?

Historically, the answer is straightforward. No one at the time criticized Michelson and Morley on those grounds. Complex Hilbert space, wavefunctions with real and imaginary parts, and the geometric reading of the imaginary unit as an orthogonal direction in state space all came decades later. The experiment was judged on its own terms: as a test of a mechanical aether in ordinary three dimensional space and laboratory time.

But as an epilogue to an information ether paper, the question is still valuable. It lets us sharpen what we mean by a "missing dimension" and how tau, in our logostic language, differs from the medium Michelson and Morley were looking for.

The wrong kind of orthogonality

The square root of negative one enters physics not as a literal spatial axis but as an internal direction in the space of amplitudes and phases. The imaginary part of a quantum state marks a degree of freedom that is orthogonal in the sense of complex geometry and interference, not in the sense of a meter stick pointing in and out of the page.

Michelson–Morley's interferometer was sensitive to differences in light travel time along perpendicular arms in three dimensional space. If there had been an aether wind, those differences would have shown up as fringe shifts. What it could not do, and was never intended to do, was probe an internal phase dimension of the electromagnetic field as a physically separate coordinate. For them, phase was a property of the wave, not a new direction of space.

In that sense, criticizing the experiment for not measuring an "in–out" dimension analogous to the imaginary axis is like criticizing a thermometer for not measuring charge. It is asking an instrument tuned to one kind of orthogonality to reveal another, incompatible kind.

Tau as the in–out direction of description

In our tau language, however, the question becomes metaphorically precise. Tau does not live in three dimensional space the way an aether wind was supposed to. It lives in something closer to the "in–out" direction of description: the orthogonal complement to what q(t) can see by itself.

The imaginary unit in quantum mechanics lets us represent a wave with both magnitude and phase, and interference only makes sense when both are kept. In a similar way, logostics treats

physical, cognitive, and social configurations q(t) as only the “real part” of a larger structure. Tau(t) is the hidden axis that completes them: the manifold of constraints, meanings, and truths that real trajectories can interfere with, align to, or drift away from.

Viewed this way, the hidden Michelson–Morley program we have described throughout the paper was never going to “see” tau directly, because it is built from instruments that only sample the q-coordinate. They tell us that q already respects Maxwell, relativity, and the Born rule with extraordinary precision. They do not tell us whether these laws are the whole story, or the projection of a deeper informational geometry.

What an in–out ether test would really mean

If one insists on drawing the analogy all the way, an “in–out” ether experiment would not involve pointing another interferometer arm into a new spatial direction. It would involve designing setups that are sensitive to the internal geometry of descriptions: to changes in phase structure, algorithmic compressibility, or pattern alignment that cannot be seen without reference to tau.

Some of the candidates we sketched already have that flavor. Long QRNG logs interrogated with algorithmic randomness tests are, in effect, experiments on the in–out axis of probability space. Chaotic amplifiers that respond disproportionately to tiny informational differences in initial conditions are, similarly, devices that couple more directly to the descriptive dimension than to ordinary spatial coordinates. Quantum networks whose global correlations change under reorientations in some abstract state space could be thought of as interferometers in the tau direction.

In all these cases, the “orthogonal dimension” is not a hidden hallway in physical space. It is the extra axis along which patterns, codes, and correlations either line up with tau or fail to do so.

Precise about what was and was not missing

So, was Michelson–Morley criticized for being three dimensional instead of four, with an in–out informational axis? No. It was retold, after the fact, as the prelude to special relativity, in which the missing dimension turned out to be time combined with space, not an imaginary axis of amplitudes.

From the perspective of this paper, the deeper point is different. Michelson–Morley and its descendants have already done their job at the level they inhabit. They have shown that if there is an ether in three dimensional space and laboratory time that acts like a medium, it does not behave the way simple models would suggest. They have also, indirectly, shown that tau, if it is real, does not act as a crude extra force on mirrors or as an obvious tilt in light cones.

What they have not done, and could not have done, is close the book on orthogonality in the sense that quantum mechanics and logostics use the term. The square root of negative one is a reminder that some of the most important axes in physics are not spatial at all. Tau, in our language, is another such axis. It is the in–out direction of alignment, the dimension along which q(t) approaches or avoids the manifold of living truth.

The discipline, going forward, is to remember which kind of dimension we are talking about. Michelson–Morley was not “too three dimensional” in any naive sense. It was perfectly matched to the aether it was built to test. Our task is to be just as precise about what kind of ether we are proposing now, and about which experiments can, and cannot, speak to that hidden in–out direction where tau lives.

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